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Combustion Engine and Method for Operating a Combustion Engine

This invention relates to a combustion engine with at least one charging unit (16) which is driven by the exhaust gas flow (28) of the combustion engine (10), and with a cam shaft adjustable according to the Miller method, a further compressor stage (32) being disposed serially or parallel to the charging unit (16), said compressor stage not being driven by the exhaust gas flow of the combustion engine (10). Moreover, it relates to a method for operating a combustion engine with at least one charging unit (16) which is driven by the exhaust gas flow (28) of the combustion engine, with a cam shaft adjustable according to the Miller method, and a further compressor stage (32) disposed serially or parallel to the charging unit (16), said compressor stage not being driven by the exhaust gas flow of the combustion engine (10), with low numbers of revolutions of the combustion engine (10) the charging pressure being increased by activation of the further compressor stage (32).

Description

[0001] This invention relates to a combustion engine with at least one charging unit which is driven by the exhaust gas flow of the combustion engine, and with a cam shaft adjustable according to the Miller method, and a method for operating this type of combustion engine.

[0002] With highly charged Otto engines, with a design with high compression in order to achieve good degrees of efficiency during partial load operation, there is a severe limitation due to pinging (or pinking), and a consequence of this is late exchange [or conversion] of the fuel/air mixture and a high standard deviation of the combustion cycles.

[0003] In order to avoid these disadvantages, with the so-called Miller method the compression state is varied by changeable closure times of the inlet valves, dependent upon the operational state. The Miller method is described for example in R. Pischinger, G. Krasnig, G. Taucar, Th. Sams "Thermo-dynamics of the internal combustion engine", Springer-Verlag, 1989, pages 296 et seq. As the load increases, i. e. with increasing charge, the inlet valve is closed earlier and earlier, partly even before the bottom dead center, so that the cylinder is only incompletely filled with fresh air. During the remaining intake stroke, the charge expands in the cylinder, and cools down. The compression begins at the expense of a lower charge mass from a lower pressure and temperature level, and the mechanical and thermal loading decrease.

[0004] The disadvantage of the reduced charge can be compensated by higher charging pressure. If one observes the state after the charge air cooler provided that there is the same charge air temperature with exhaust gas turbocharging and with the Miller method, the following applies with reference to **Fig. 1**: In a complete four-stroke comparison process the compression (1) on the level of the charging pressure (1') begins with normal exhaust gas turbocharging, see **Fig. 1,** left hand diagram. With the Miller method, see **Fig. 1**, right hand diagram, due to the premature closure of the inlet valve, the

cylinder pressure falls at the start of compression (1) to below the level of the charging pressure (1'). Provided that there is the same cylinder pressure at the start of compression, with the Miller method there is more charge with a lower temperature in the cylinder than with the exhaust gas turbocharging. The excess work gained in this way in the high pressure phase with the same air ratio is however consumed again to a considerable extent by the higher gas exchange work. With diesel engines, the Miller method therefore only offers small advantages. It is therefore mainly used with Otto engines because here, the lower compression final temperature offers true advantages with regard to knocking, and so clearly higher performances can be achieved.

[0005] Engines working according to the Miller method, which close with extremely early or late inlet, thus involve a reduced use of the stroke volume, and this results in lower torque. Provided a sufficient mass of exhaust gas is provided, this disadvantage can be equalized (or balanced) by stronger closure of the wastegate of the exhaust gas turbocharger. Due to this, the charging pressure increases. The disadvantage of this solution is that with low numbers of revolutions, the wastegate is already maximally closed. With combustion engines working according to the Miller method, in this operational range this leads to a reduction of the maximum achievable torque.

[0006] The object of this invention is therefore to further develop a combustion engine of the type specified initially above and the method specified initially above such that a higher torque can be achieved with a low number of revolutions.

[0007] This object is fulfilled by a compression engine with the features of Claim 1 and by a method for operating a compression engine with the features of Claim 5.

[0008] The invention is based upon the knowledge that with low numbers of revolutions, higher torque can be achieved if the charge of the charging unit is supported by a further compressor stage disposed serially or parallel to the

exhaust gas turbocharger, the drive of which does not depend upon the exhaust gas flow. This further compressor stage can for example be driven mechanically or electrically. In this way, with low numbers of revolutions, the charging pressure of the charging unit, in the above example of the exhaust gas turbocharger, can already be increased.

[0009] The additionally used mass of air brings about an increase in torque, and at the same time the higher mass flow at the turbine of the charging unit brings about higher drive power on the compressor of the charging unit, by means of which the power input for increasing the charging pressure remains low.

[0010] In particular, the invention also embraces the electrical support of a charging unit which is used with a combustion engine according to the invention.

[0011] With serial arrangement of the charging unit and the further compressor stage, the advantages of the invention, with arrangement of the further compressor stage, can be realized before or after the charging unit. If the additional compressor stage is disposed before the charging unit, this results in air being supplied to the charging unit with a higher charging pressure. Conversely, with an arrangement of the further compressor stage after the charging unit with low numbers of revolutions, the supply of air to the combustion engine is substantially undertaken by the further compressor stage. Preferably, with higher numbers of revolutions, the further compressor stage is bypassed, because then the charging unit can itself make sufficient charging pressure available due to the high flow of exhaust gas.

[0012] The charging unit can comprise an exhaust gas turbocharger, a screw compressor, a Roots compressor or a spiral charger, or combinations of these charging units in order to increase the supply of air to a combustion engine.

[0013] The further compressor stage is preferably driven mechanically or electrically, and in particular comprises an electric booster.

[0014] With the solution according to the method according to the invention, with low numbers of revolutions of the combustion engine, the charging pressure is increased by activating the further compressor stage.

[0015] With a preferred embodiment, the charging unit has a wastegate, and the further compressor stage is only activated when the wastegate is already closed, and furthermore there is a difference between the ideal torque and the actual torque of the combustion engine.

[0016] Further advantageous further developments of the invention are defined in the dependent claims.

[0017] In the following, an example of an embodiment is described in greater detail with reference to the attached drawings:

[0018] **Fig. 1** shows, in schematic form, PV diagrams with ideal constant space/constant pressure combustion with a conventional exhaust gas turbocharger (left-hand diagram) and according to the Miller method (right-hand diagram), and

[0019] **Fig. 2** shows an example of an embodiment of a combustion engine according to the invention.

[0020] **Fig. 2** shows, in schematic form, a combustion engine 10 including a charging unit 12. Air is supplied to the actual engine 14 by means of an exhaust gas turbocharger 16 which comprises a compressor 18 and a turbine 20, by means of a charge air cooler 22. The engine 14 functions according to the Miller method and comprises a cam shaft adjustable according to the Miller method (not shown). The exhaust gas turbocharger 16 further comprises a wastegate 24 with a control line 26, by means of which, in particular with high

numbers of revolutions of the engine 14, air can be conveyed past the turbine 20. The arrow 28 identifies the air leaving the combustion engine. The arrow 30 indicates the air flowing into the combustion engine 10 according to the invention. The inflowing air initially passes through an electric booster 32 which comprises an electric motor 36 controlled by electronics 34 with a shaft 38 on which a compressor 40 is disposed. The electric booster 32 is disposed serially to the exhaust gas turbocharger 16. The electric booster is disposed serially to the exhaust gas turbocharger 16. Parallel to the electric booster 32, a bypass line 42 is disposed with a valve 44. The valve 44 can also be controlled by the electronics 34.

[0021] Mode of operation: With low numbers of revolutions only a small volume of exhaust gas flow flows through the turbine 20, and this is why the compressor 18 assigned to the turbine 20 only establishes a low charging pressure. According to the invention, in particular in this operating state, the electric motor 36 is activated, and this leads to activation of the compressor 40. As soon as the compressor 40 is set in operation, it supplies air with increased charging pressure to the compressor 18. As soon as the control electronics determine that the exhaust gas flow is sufficient, for example by assessing the revolutions of the engine 14, to make sufficient charging pressure available without the help of the electric booster 32, the valve 44 is opened so that the electric booster 32 is bypassed.

[0022] The electric motor 36 can be supplied purely by the vehicle generator, or by a combination of the generator and the vehicle battery. The wastegate 24 is opened if it is determined, for example using the revolutions of the engine 14, that the engine can make available sufficient power without charging or with reduced charging.

[0023] Preferably, a difference between the desired torque and the actual torque of the combustion engine is determined in the vehicle – the ideal torque for example from the position of the accelerator pedal. The electric booster 32 is preferably activated when the wastegate 24 of the exhaust gas turbocharger

16 is already closed, and there is furthermore a difference between the desired torque and the actual torque of the combustion engine.

Patent Claims

1. A combustion engine with at least one charging unit (16) which is driven by the exhaust gas flow (28) of the combustion engine, and with a cam shaft adjustable according to the Miller method, **characterized in that** a further compressor stage (32) is disposed serially or parallel to the charging unit (16), said compressor stage not being driven by the exhaust gas flow of the combustion engine (10).

2. The combustion engine according to Claim 1, characterized in that the further compressor stage (32) is disposed before or after the charging unit (16).

3. The combustion engine according to Claim 1 or 2, characterized in that the charging unit (16) comprises an exhaust gas turbocharger, a screw compressor, a Roots compressor or a spiral charger, or combinations of these charging units, in order to increase the supply of air to the combustion engine (10).

4. The combustion engine according to any of the preceding claims, characterized in that the further compressor stage (32) comprises a mechanically or electrically driven charging unit, in particular an electric booster.

5. A method for operating a combustion engine with at least one charging unit (16) which is driven by the exhaust gas flow (28) of the combustion engine, with a cam shaft adjustable according to the Miller method, and a further compressor stage (32) disposed serially or parallel to the charging unit (16), said compressor stage not being driven by the exhaust gas flow of the combustion engine (10), with low numbers of revolutions of the combustion engine (10) the charging pressure being increased by activating the further compressor stage (32).

6. The method according to Claim 5, characterized in that the charging unit has a wastegate (24), and the further compressor stage (32) is activated only if

the wastegate (24) is already closed and furthermore if there is a difference between the desired torque and the actual torque of the combustion engine.

2 pages of drawings attached